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Use of FLUKA in the Analysis of the Mars Odyssey MARIE Experiment

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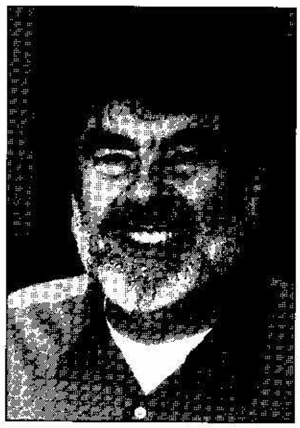
Abstract—UH researchers have significantly improved the calibration of the MARIE by simulating its response to energetic protons using FLUKA. Analysis of MARIE data shows that the intensity of solar energetic particles depends strongly on how well the observation point is connected magnetically to the site at which the particles are accelerated.



Dr. Lawrence S. Pinsky

MARIE IS A CHARGED PARticle telescope aboard Mars Odyssey designed to detect energetic nuclei. The instrument characterizes the radiation environment at Mars as an aid in planning eventual manned missions to the planet. In addition, the data, if properly calibrated, is also useful in the study of the transport of galactic cosmic rays and solar energetic particles in the inner heliosphere. Unfortunately, MARIE received relatively little calibration before it was launched; in order to completely calibrate the data from MARIE, we must thus rely on detailed simulations of the transport of particles through the instrument.

Results

MARIE consists of a stack of silicon detectors of different thickness. As energetic charged particles traverse the detectors, they deposit energy in the detectors. The amount of energy deposited depends on both the kinetic energy of the particle as well as its charge. Each silicon detector returns a measured voltage proportional to the energy deposited in that detector; we calibrate the data by fitting a relation between the observed data and simulated data. A plot of raw data from two of MARIE's detectors is shown in Fig. 1. Simulated data for the same set of detectors is shown in Fig. 2. Note the excellent correspondence between the actual and simulated data. With these simulations, we have been able to significantly improve the calibration of the MARIE data.

A plot of the observed particle fluxes in MARIE's A1 detector over an 18-month period is shown in Fig. 3 (lower panel) compared to fluxes measured by the Solar Isotope Spectrometer (SIS) aboard ACE (upper panel). Even a cursory examination of Fig. 3 shows that sometimes there is a good correlation between solar particle events (SPEs) observed with different instruments,

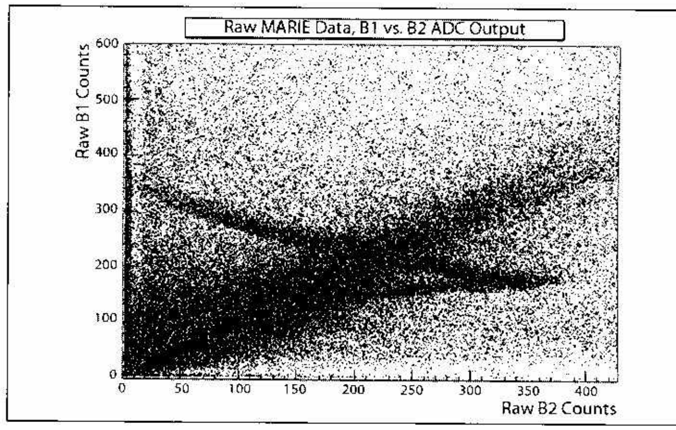


Figure 1. Raw data for a pair of MARIE detectors. The voltages have been converted to an arbitrary scale by an analog to digital converter (ADC). There are several features visible on the plot; the diagonal line from upper right to lower left is due to higher energy nuclei of different species; the line making the greater than symbol (>) is due to low energy protons, and the spray of points that covers the diagram is due to particles that have experienced a nuclear reaction in one of the detectors.

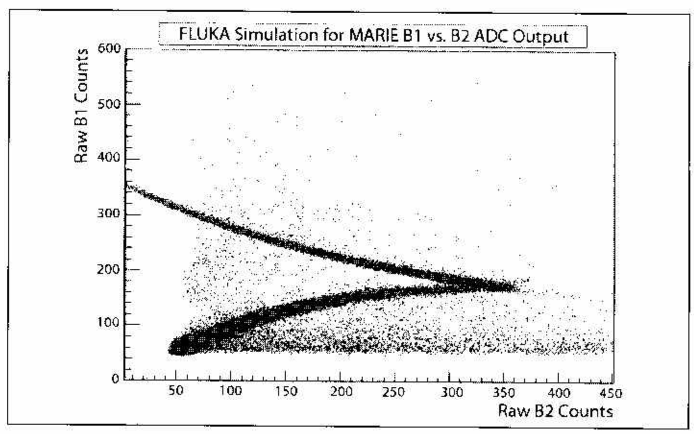


Figure 2. Simulations of low energy protons for the same pair of detectors plotted in Fig. 1.

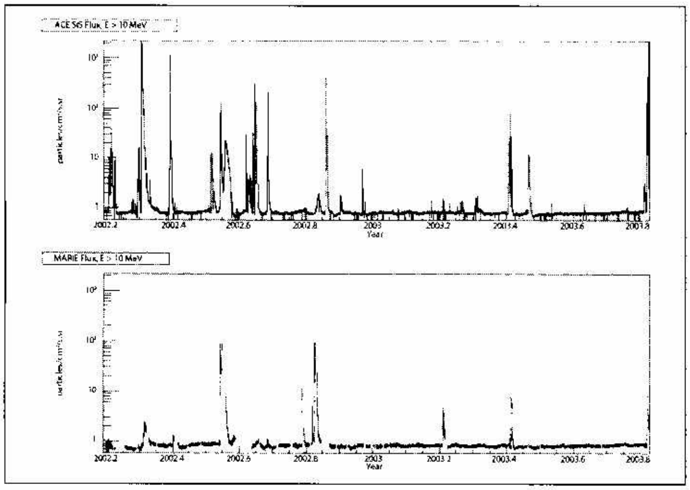


Figure 3. A comparison of the flux of energetic protons near Earth (*upper panel*) and near Mars (*lower panel*). The times where the flux increases rapidly indicate particles accelerated by solar activity; the persistent low level background is due to galactic comic rays.

while at other times the conditions at the different locations seem completely independent of one another. This is a result of the way that the SPE particles propagate away from their acceleration sites. Particles are constrained to move along the solar magnetic field lines, which, roughly speaking, follows an Archimedian spiral outward from the Sun.[1] Thus, when Earth and Mars are connected to the same set of magnetic field lines, they see similar particle events; if they are connected to significantly different sets of field lines, the level of SPE particles can vary substantially. In fact, in the most extreme case where the field lines to which the two planets are connected are separated by 180 degrees, there is essentially no correlation between the fluxes observed. Figure 4 illustrates this point; the SPEs observed at both Mars and Earth, as well as those that are observed at only Mars, are clustered around the solar longitude of best connection for Mars. On the other hand, those events observed only at Earth tend to originate in the quadrant diametrically opposed to the longitude of best connection for Mars.

References

[1]A. Fasso, A. Ferrari, and P. R. Sala, "Electron-Photon Transport in FLUKA: Status," *Proc.*, Monte Carlo 2000 Conf., Lisbon, Portugal, Oct. 23–26, 2000; (2001): 159-64.

[2]A. Fasso, A. Ferrari, J. Ranft, and P. R. Sala, "FLUKA: Status and Prospective for Hadronic Applications," *Proc.*, Monte Carlo 2000 Conf., Lisbon, Portugal, Oct. 23–26, 2000; (2001): 955-60.

Thesis

Lee, K. "Martian Radiation Environment Experiment (MARIE)," dissertation in progress, UH, Jan. 2001–present. Funding obtained: $25,894 (NAG9-1347).

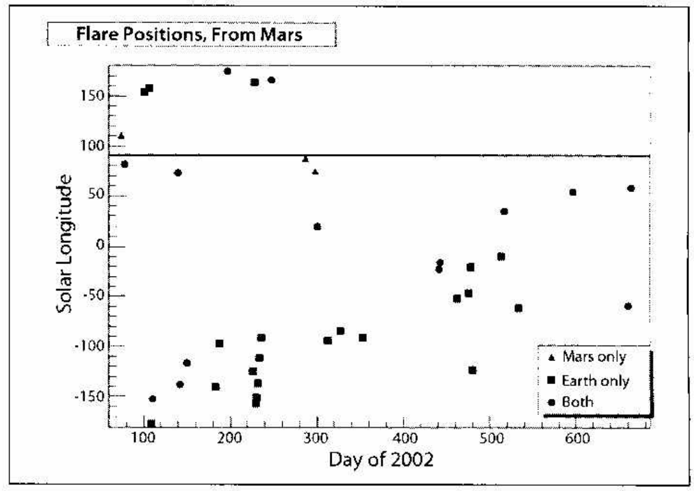
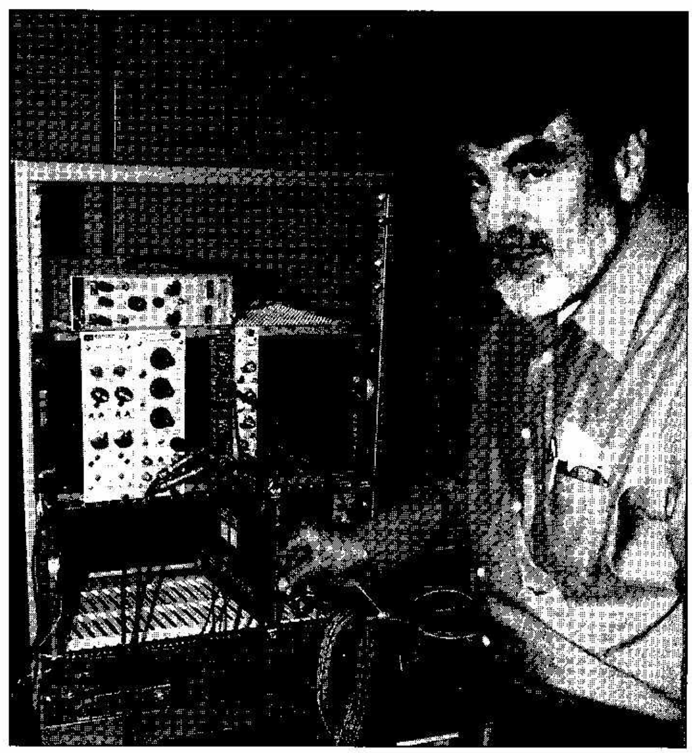


Figure 4. A plot of the solar longitude (as seen from Mars) from which SPEs originated as detected: Mars only (triangles), Earth only (squares), and both locations (circles). The straight line at longitude of +90 degrees indicates the nominal longitude of best magnetic connection for Mars, assuming a solar wind speed of 400 km/s. Note that the events detected at Earth, but not at Mars, originated from a range of longitudes 180 degrees opposed to the longitude of best connection for Mars (i.e., originated from longitudes centered around −90 degrees).



FRONT END BOARDS—Dr. Pinsky developes equipment designed to detect charged particles by which scientists are able to measure differences up to 1 nanosecond.